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Charged Particle and Neutron Backgrounds in an $e^{-}e^{-}$ Interaction Region at the NLC

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CHARGED PARTICLE AND NEUTRON BACKGROUNDS IN AN e^-e^- INTERACTION REGION AT THE NLC.

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We compare the detector background situation in an e^-e^- interaction region at the NLC with previous studies done of the NLC e^+e^- interaction region. We note from previous studies that the dominant source of detector backgrounds are the beamstrahlung pairs. Since these scale with luminosity, the reduction in luminosity in e^-e^- collisions leads to a reduction in detector backgrounds compared to the e^+e^- situation.

1. Introduction

The layout of an e^+e^- interaction region has been studied in detail and reported in the proceedings of the LCWS series of workshops,[1] in the recent design reports of the NLC, JLC and TESLA accelerator projects[2] and in the Proceedings of the 1996 Snowmass workshop.[3]

The latest results of background studies in the NLC e^+e^- interaction region and a detailed discussion of interaction region design criteria are reported in the Proceedings of the LCWS conference at Sitges.[4] In this paper we review the key points learned from the study of the e^+e^- interaction region backgrounds. Evaluating the differences between e^+e^- and e^-e^- interactions then allows us to extrapolate the e^+e^- detector backgrounds to the e^-e^- case.

2. Detector Backgrounds in the e^+e^- interaction region

Figure 1 shows the current magnet and mask layout in the interaction region (IR) of the NLC small detector along with the beampipe and the vertex detector. The detector elements must be protected from charged particle and neutron backgrounds produced by operation of the accelerator and by the beam–beam interactions at the interaction point(IP). The first layer of the vertex detector is closest to the interaction point and therefore most susceptible to these backgrounds. Recommended limits for backgrounds in the vertex detector are shown in Table 1.[5] The various sources of background particles are listed in Table 2.

2.1. *Charged Particle Backgrounds*

Previous studies of e^+e^- interactions have shown that the beamstrahlung pairs are the largest source of charged particle hits in the vertex detector. The pairs are produced at the IP and spiral around the 6 Tesla solenoidal magnetic field. Figure 2

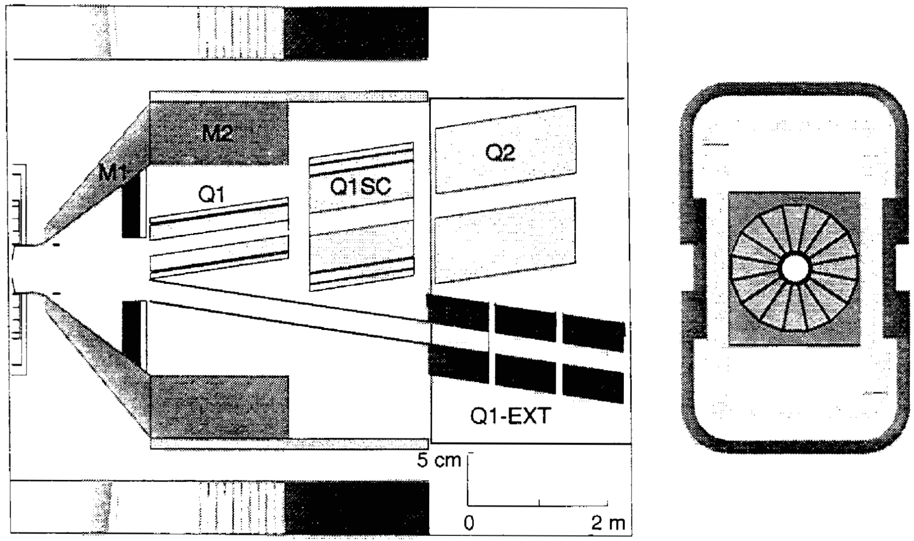

Fig. 1. The interaction region masking and magnet layout. At right is the cross section view of the Q1 REC magnet in its stiffening structures.

Table 1. Background limits in the detector.

Vertex Detector:		SI Tracker:	
$e^{\pm}$ hit density	$< 1/\text{mm}^2/\text{year}$	$e^{\pm}$ hit density	$< 0.1\%$ occupancy
neutron hit density	$< 3 \times 10^9/\text{cm}^2/\text{year}$	Drift Chamber	$< 10\text{K}\gamma/\text{train}$

shows the position along the beam direction where each particle first reaches it's largest radius.

Recent work has studied the complete history of beamstrahlung pairs which produce background hits in the vertex detector. While some e^+e^- pairs are produced with sufficient transverse momentum that they travel directly to the vertex detector, the majority of hits come from a different source. If we examine a field line of the detector solenoid which passes through the first layer of the vertex detector, we see that it travels into the outgoing beamline before intersecting the beampipe wall. This means that low energy particles produced by beamstrahlung pairs showering

Table 2. Detector background sources.

Machine Backgrounds	IP Backgrounds
Direct beam loss	Disrupted primary beam
beam–gas scattering	Beamstrahlung photons
collimator edge scattering	e^+e^- pairs from beam–beam interactions
Synchrotron radiation	Radiative Bhabhas
Muons Production	Hadrons from $\gamma\gamma$ interactions
Neutron back-shine from Dump	
Extraction Line Loss	

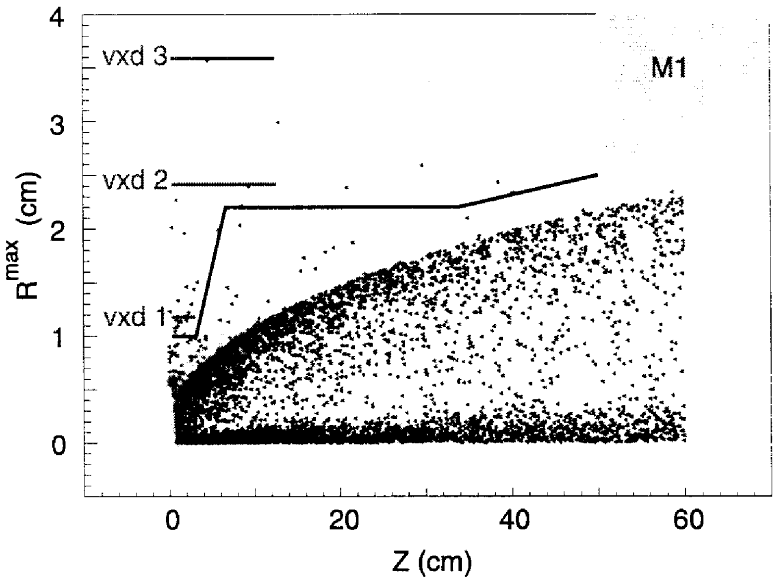

Fig. 2. R^{max} vs. Z distribution of pairs. Three vertex detector layers and the beam pipe are indicated.

in the beam pipe wall have a clear path to spiral back along the magnetic field to the first layer of the vertex detector. Since these particles follow a well defined path it is possible to place material along this path to absorb them. Figure 1 shows a cylinder of material just inside the mask M1 which was included to absorb these particles. The numbers of charged hits in the layer 1 vertex detector is reduced from 10 hits/mm^2/train to 2 hits/mm^2/train with the addition of this material.

2.2. *Neutron Backgrounds*

Neutrons are produced primarily through the giant dipole resonance when background particles shower in material and produce low energy photons. Studies have shown that the beamstrahlung pairs are the major source of neutron fluence that reaches the IP even though the disrupted beam and beamstrahlung photons carry the majority of the beam energy, see Table 3.

Table 3. The total energy carried by outgoing particles.

	Outgoing energy (GeV)	Shower point
Disrupted beam	9×10^{12}	dump
Beamstrahlung	9×10^{11}	dump
e^+e^- pairs	8×10^5	IR masks and outgoing beamline

Detailed studies of the histories of neutrons produced by beamstrahlung pairs shows that while neutrons are produced all along the outgoing beamline only those produced close to the IP are likely to reach the IP. Figure 3 plots the weight of

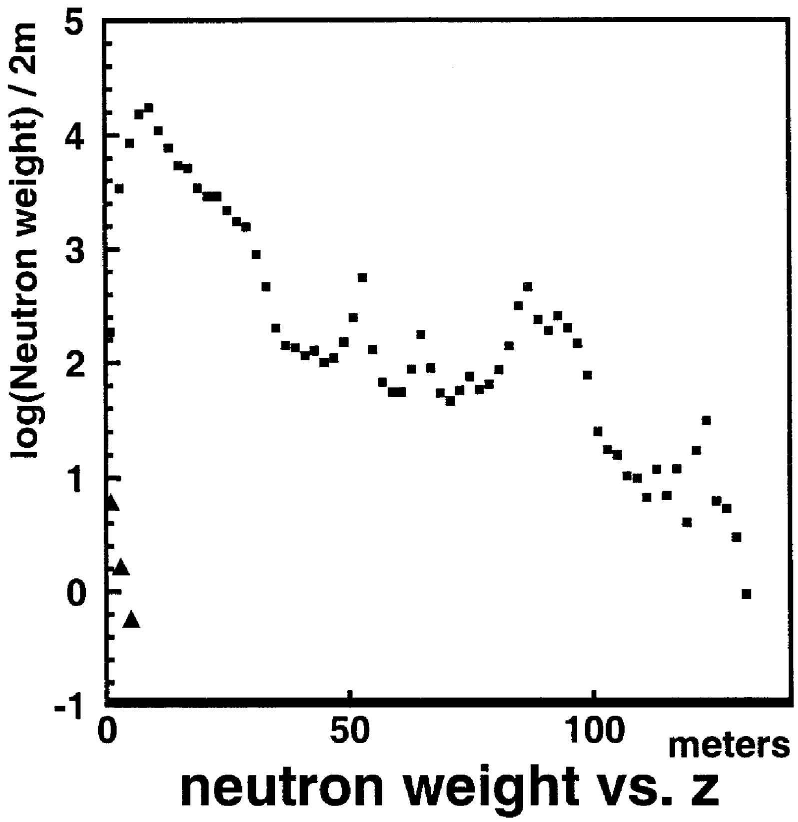

Fig. 3. A comparison of the position along the beam line of all neutrons produced (squares) with those that reach the IP (triangles).

neutrons produced versus their location along the beamline for all neutrons and for neutrons which reach the IP. The majority of neutrons that reach the IP are produced by beamstrahlung pairs which shower in the tip of mask M1.

3. e^-e^- Backgrounds

To evaluate the e^-e^- backgrounds we start with the standard parameters for the 1 TeV NLC-B machine and the current layout of the focusing magnets and masks for the small detector option, as shown in Figure 1. We then replace the e^+ beam with an e^- beam. Machine backgrounds should be unchanged by this substitution, however, IP backgrounds will be different. There is an increased disruption of the bunches during e^-e^- interactions which leads to a reduction of the machine luminosity by a factor of three. The beamstrahlung pairs and radiative Bhabhas are reduced by the same factor. The angular distribution of the disrupted outgoing beam is also different from the e^+e^- case, as shown in Figure 4.

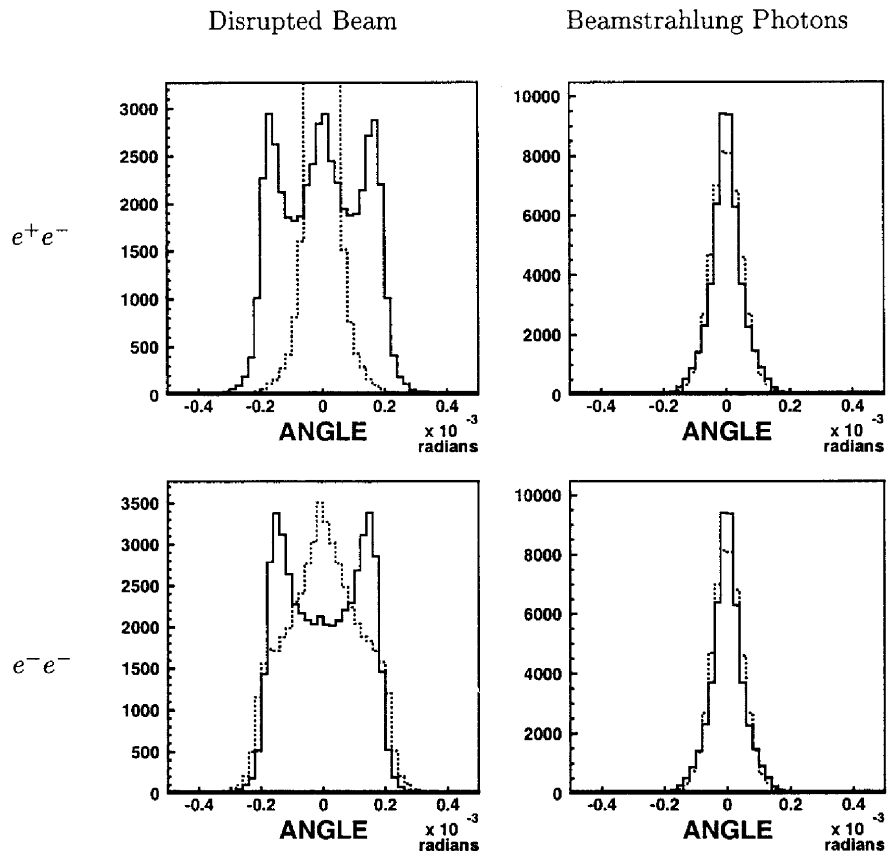

Fig. 4. The angular distribution of the disrupted beam and beamstrahlung photons. The solid line is the angle in x and the dotted line the angle in y.

Since the detector backgrounds are dominated by the beamstrahlung pairs in the e^+e^- case they should be reduced by a factor of three in the e^-e^- case. A sample of beamstrahlung pairs was generated for the e^-e^- case using the Guineapig program. The charged hits and the neutron fluence from these pairs was simulated using the geant and fluka programs, respectively. The results were consistent with a reduction of the backgrounds from this source by a factor of three.

The change in the angular distribution of the disrupted beam, Figure 4, leads to more lost particles in the outgoing beamline. While the number of lost particles could be reduced by redesigning the outgoing beamline, we can use the current beamline as a worst case scenario to determine whether the neutron fluence at the IP from these lost particles is significant. Geant simulations of the outgoing beam line show an increase of a factor of ten in the number of lost particles in the e^-e^- case. We assume the neutron fluence from these lost particles also increases by a factor of ten.

In Table 4 we compare the neutron fluences from the various background sources for the e^+e^- and e^-e^- cases. As can be seen the beamstrahlung pairs are the dominant source of neutrons in the e^+e^- case with neutrons from the beam dump an order of magnitude smaller. In the e^-e^- case the beamstrahlung pairs are still dominant but the neutrons from the dump are no longer negligible and the neutrons from lost particles becomes comparable to those from the dump. The overall reduction in neutron fluence at the IP is a factor of two.

Table 4. The neutron fluence at the IP ,$\times 10^9$ hits/cm^2/year, from the background sources in the e^+e^- and e^-e^- cases.

	e^+e^-	e^-e^-
beam-beam pairs	1.7	0.6
Radiative Bhabas	0.02	0.02
Disrupted Beam		
Lost in dump line	0.01	0.1
Back-shine from dump	0.2	0.2
Beamstrahlung		
Back-shine from dump	0.05	0.05
Total:	1.98	0.97

4. Conclusions

The current simulation of the e^+e^- collider shows that the beamstrahlung pairs are the dominant source of charged particle hits in vertex detector layer 1 and the dominant source of neutron fluence at the IP. An e^-e^- collider using the same machine parameters has a loss of luminosity of a factor of three. This reduces the number of beamstrahlung pairs by the same amount, with a concomitant reduction in backgrounds.

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